Authors: Theo L.B. Le Roux, Felipe Gómez-García, René Espinosa-Mendoza

QUESTION 4: What is the diagnostic accuracy of magnetic resonance imaging (MRI) for osteomyelitis in the presence and absence of implants?

RECOMMENDATION: MRI is useful for the diagnosis of osteomyelitis in the absence of metal implants, although there are other diagnostic tools that show greater specificity and sensitivity. The pooled sensitivity and specificity for MRI in diagnosing osteomyelitis without presence of implants are 84% and 60%, respectively. There are no identifiable studies on the diagnostic accuracy of MRI for osteomyelitis around metal implants. Several techniques for reducing metal artifacts exist.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 96%, Disagree: 1%, Abstain: 3% (Unanimous, Strongest Consensus)

RATIONALE

Diagnostic Accuracy of MRI for Osteomyelitis in Absence of Implants

A variety of diagnostic imaging techniques are available for excluding or confirming chronic osteomyelitis, including plain radiography, computed tomography, bone scintigraphy, leukocyte scintigraphy, gallium scintigraphy, combined bone and leukocyte scintigraphy, combined bone and gallium scintigraphy, fluorodeoxyglucose positron emission tomography and MRI [1–6].

Each of these techniques have varying degrees of sensitivity, specificity and diagnostic accuracy. The Termaat's study [7] (Table 1) shows that the sensitivity and specificity of magnetic resonance imaging is sufficiently homogeneous (Q_{sens} = 4.62: four degrees of freedom, Q_{spec} = 0.02: two degrees of freedom) for chronic osteomyelitis in the peripheral skeleton and was not different from that of leukocyte scintigraphy or combined bone and gallium scintigraphy for the studies in this systematic review [7–28].

The literature demonstrates that MRI is useful for the diagnosis of osteomyelitis in the absence of metal implants, although there are other diagnostic tools that show greater specificity and sensitivity.

Diagnostic Accuracy of MRI for Osteomyelitis in Presence of Metallic Implants

There are no identifiable studies on the diagnostic accuracy of MRI for osteomyelitis around metal implants. There are five studies providing some information on this topic.

Table 1. Sensitivity and specificity of various imaging techniques [7]

Type of Study	Pooled Sensitivity (95% CI)	Pooled Specificity (95% CI)
Bone scintigraphy	82% (70% – 89%)	25% (16% – 36%)
Leukocyte scintigraphy	61% (43% – 76%)	77% (63% – 87%)
Combined bone and leukocyte scintigraphy	78% (72% – 83%)	84% (75% – 90%)
Fluorodeoxyglucose positron emission tomography	96 % (88% – 99%)	91% (81% – 95 %)
Magnetic Resonance	84% (69 – 92 %)	60% (38% – 78%)
Radiography	ND	ND
Computed tomography	ND	ND
Combined bone and gallium scintigraphy	ND	ND

Gallium scintigraphy	ND	ND

CI, confidence interval; ND, no data

Jiang et al. [29] analyzed 16 patients who received tumor resection and joint replacement for bone cancer. They were retrospectively analyzed to identify MRI features that were useful for the diagnosis of periprosthetic infection and tumor recurrence using the optimized MRI parameters with and without view angle tilting (VAT) correction at 1.5 T in coronal fast-spin-echo T2-weighted MRI. Irregular soft tissue mass, soft tissue edema, bone destruction and fistula were significant features of periprosthetic infection, with sensitivities of 47.4 to 100% and specificities of 73.1 to 100.0%, which were confirmed based on surgical and pathological findings. Soft tissue masses were a significant feature of tumor recurrence, with 100% sensitivity, 96.0% specificity and 97.0% consistency.

Jungman et al. [30] found that significant reduction of artifacts was achieved by VAT ($p < 0.001$) and VAT and slice encoding for metal artifact correction (SEMAC) ($p = 0.003$) when compared with conventional pulse sequences. On clinical MRIs, artifact diameters were significantly reduced and diagnostic confidence improved ($p < 0.05$). In 2 cases tumor-recurrence was diagnosed, in 10 cases infection was diagnosedand in 13 cases other .pathology was diagnosed

Fritz et al. [31] mention that optimized conventional pulse sequences and metal artifact reduction techniques afford improved depiction of bone, implant-tissue interfaces and periprosthetic soft tissue for the diagnosis of arthroplasty-related complications. They present strategies for MR imaging factors and parameters for: (a) minimization of arthroplasty-related artifacts (imaging at 1.5 T, instead of 3 T, fast spin-echo (SE) sequence, instead of gradient-echo sequences, high receiver (readout) bandwidth, thin sections) and (b) optimization of image quality (use of intermediate echo time, which results in fluid-sensitive images, instead of T1-weighted or heavily T2-weighted imaging, large matrix in the frequency direction (e.g., 512), high number of excitations and inversion-recovery fat suppression, instead of frequency-selective fat suppression). They concluded that MRI is effective for the assessment of the periprosthetic soft tissues in patients who have had a total hip arthroplasty (THA).

Alprandi et al. [32] demonstrated the diagnostic value of MRI when measuring and characterizing periprosthetic fluid collections (classified as serous/purulent/hematic according to signal behavior). For all evaluations, inter-observer agreement was 100%. No significant differences were found between the measurements of the collections ($p > 0.258$). The authors agree that MRI is highly reproducible in detection, localization, quantification and characterization of fluid collections when the presence of implant infection is clinically suspected.

White et al. [33] investigated the use of standard MRI sequences with simple parameter modifications in 14 THAs for the detection and characterization of THA complications and conclude that by using simple modifications to standard MR imaging sequences, diagnostic-quality MR imaging of THA complications can be performed, particularly around the femoral prosthetic stem.

Magnetic Resonance Imaging Considerations

Attempts have been made to obtain a Metal Artifact Reduction Sequence (MARS) to reduce the size and intensity of magnetic susceptibility artifacts resulting from magnetic field distortion. Artifacts are encountered especially while imaging near metallic implants and result from local magnetic field inhomogeneities introduced by the metallic object into the otherwise homogeneous external magnetic field.

A variety of techniques are used for reducing metal artifacts in MRI. Some techniques proposed include single point imaging, prepolarized MRI, VAT, multiacquisition variable-resonance image combination (MAVRIC) and SEMAC. Changes to the scan protocol can address artifacts due to the presence of metal in the image plane (in-plane artifacts) and due to metal in an adjacent plane (through-plane artifacts) [34]. MAVRIC is a specialized sequence to minimize metallic artifact around metallic prostheses [35]. It relies on 3D fast spin echo (FSE) sequences, using multiple different overlapping volumes at different frequency offsets. Another technique used for addressing through-plane metal artifacts is SEMAC, where an additional slice-encoding gradient is added to a standard fast-spin echo sequence [36]. The combination of the MAVRIC and SEMAC technique is known as multiacquisition variable-resonance image combination selective (MAVRIC-SL) sequence[37].

Conclusions

The literature shows that MRI can be useful in the diagnosis of osteomyelitis in the absence of metal implants, although there are other diagnostic tools that show greater specificity and sensitivity. There is a paucity of data regarding the diagnostic value of MRI for osteomyelitis in presence of metallic implants. Several techniques for reducing the artifacts seen on MRI exist and others are in development, but there is no clinical data about the diagnostic accuracy of osteomyelitis for MRI in this setting.

REFERENCES

[1] Love C, Tomas MB, Marwin SE, Pugliese P V., Palestro CJ. Role of nuclear medicine in diagnosis of the infected joint replacement. RadioGraphics. 2001;21:1229–1238. doi:10.1148/radiographics.21.5.g01se191229.

[2] Gemmel F, Van Den Wyngaert H, Love C, Welling MM, Gemmel P, Palestro CJ. Prosthetic joint infections: Radionuclide state–of–the–art imaging. Eur J Nucl Med Mol Imaging. 2012;39:892–909. doi:10.1007/s00259–012–2062–7.

[3] Glaudemans AW, Galli F, Pacilio M, Signore A. Leukocyte and bacteria imaging in prosthetic joint infection. Eur Cell Mater. 2012;25:61–77. doi:10.22203/eCM.v025a05.

[4] Palestro CJ. Nuclear medicine and the failed joint replacement: Past, present, and future. World J Radiol. 2014;6:446. doi:10.4329/wjr.v6.i7.446.

[5] Kwee TC, Kwee RM, Alavi A. FDG–PET for diagnosing prosthetic joint infection: Systematic review and metaanalysis. Eur J Nucl Med Mol Imaging. 2008;35:2122–2132. doi:10.1007/s00259–008–0887–x.

[6] Verberne SJ, Raijmakers PG, Temmerman OPP. The accuracy of imaging techniques in the assessment of periprosthetic hip infection: a systematic review and meta–analysis. J Bone Joint Surg Am. 2016;98:1638–1645. doi:10.2106/JBJS.15.00898.

[7] Termaat MF, Raijmakers PG, Scholten HJ, Bakker FC, Patka P, Haarman HJ. The accuracy of diagnostic imaging for the assessment of chronic osteomyelitis: a systematic review and meta–analysis. J Bone Jt Surg. 2005;87:2464–2471. doi:10.2106/JBJS.D.02691.

[8] Wang GL, Zhao K, Liu ZF, Dong MJ, Yang SY. A meta–analysis of fluorodeoxyglucose–positron emission tomography versus scintigraphy in the evaluation of suspected osteomyelitis. Nucl Med Commun. 2011;32:1134–1142. doi:10.1097/MNM.0b013e32834b455c.

[9] Dinh MT, Abad CL, Safdar N. Diagnostic Accuracy of the physical examination and imaging tests for osteomyelitis underlying diabetic foot ulcers: meta–analysis. Clin Infect Dis. 2008;47:519–527. doi:10.1086/590011.

[10] Kapoor A, Page S, LaValley M, Gale DR, Felson DT. Magnetic resonance imaging for diagnosing foot osteomyelitis: A meta–analysis. Arch Intern Med. 2007;167:125–132. doi:10.1001/archinte.167.2.125.

[11] Hake ME, Oh JK, Kim JW, Ziran B, Smith W, Hak D, et al. Difficulties and challenges to diagnose and treat post–traumatic long bone osteomyelitis. Eur J Orthop Surg Traumatol. 2015;25:1–3. doi:10.1007/s00590–014–1576–z.
[12] Vijayanathan S, Butt S, Gnanasegaran G, Groves AM. Advantages and limitations of imaging the musculoskeletal system by conventional radiological, radionuclide, and hybrid modalities. Semin Nucl Med. 2009;39:357–368. doi:10.1053/j.semnuclmed.2009.07.001.
[13] Gotthardt M, Bleeker–Rovers CP, Boerman OC, Oyen WJ. Imaging of inflammation by pet, conventional scintigraphy, and other imaging techniques. J Nucl Med Technol. 2013;41:157–169. doi:10.2967/jnumed.110.076232.
[14] Bires AM, Kerr B, George L. Osteomyelitis: an overview of imaging modalities. Crit Care Nurs Q. 2015;38:154–164. doi:10.1097/CNQ.0000000000000056.
[15] Bohndorf K. Infection of the appendicular skeleton. Eur Radiol Suppl. 2004;14. doi:10.1007/s00330–003–2039–9.
[16] Glaser C, Matzko M, Reiser M. [Chronic infections of the skeletal system. Their imaging diagnosis]. Radiologe. 2000;40:547–556.
[17] Gross T, Kaim AH, Regazzoni P, Widmer AF. Current concepts in posttraumatic osteomyelitis: a diagnostic challenge with new imaging options. J Trauma. 2002;52:1210–1219. doi:10.1097/00005373–200206000–00032.
[18] Kaim A, Gross T, von Schulthess G. Imaging of chronic posttraumatic osteomyelitis. Eur Radiol. 2002;12:1193–1202. doi:10.1007/s00330–001–1141–0.
[19] Palestro CJ. Radionuclide imaging of osteomyelitis. Semin Nucl Med. 2015;45:32–46. doi:10.1053/j.semnuclmed.2014.07.005.
[20] Palestro CJ, Love C, Miller TT. Infection and musculoskeletal conditions: imaging of musculoskeletal infections. Best Pract Res Clin Rheumatol. 2006;20:1197–1218. doi:10.1016/j.berh.2006.08.009.
[21] Pineda C, Espinosa R, Pena A. Radiographic imaging in osteomyelitis: the role of plain radiography, computed tomography, ultrasonography, magnetic resonance imaging, and scintigraphy. Semin Plast Surg. 2009;23:80–89. doi:10.1055/s–0029–1214160.
[22] Prandini N, Lazzeri E, Rossi B, Erba P, Parisella MG, Signore A. Nuclear medicine imaging of bone infections. Nucl Med Commun. 2006;27:633–644. doi:10.1097/00006231–200608000–00006.
[23] Sia IG, Berbari EF. Infection and musculoskeletal conditions: osteomyelitis. Best Pract Res Clin Rheumatol. 2006;20:1065–1081. doi:10.1016/j.berh.2006.08.014.
[24] Stumpe KD, Strobel K. Osteomyelitis and arthritis. Semin Nucl Med. 2009;39:27–35. doi:10.1053/j.semnuclmed.2008.08.003.
[25] van der Bruggen W, Bleeker–Rovers CP, Boerman OC, Gotthardt M, Oyen WJ. PET and SPECT in osteomyelitis and prosthetic bone and joint infections: a systematic review. Semin Nucl Med. 2010;40:3–15. doi:10.1053/j.semnuclmed.2009.08.005.
[26] Widmer AF. New developments in diagnosis and treatment of infection in orthopedic implants. Clin Infect Dis. 2001;33 Suppl 2:S94–S106. doi:10.1086/321863.
[27] Kaim A, Ledermann HP, Bongartz G, Messmer P, Müller–Brand J, Steinbrich W. Chronic post–traumatic osteomyelitis of the lower extremity: comparison of magnetic resonance imaging and combined bone scintigraphy/immunoscintigraphy with radiolabelled monoclonal antigranulocyte antibodies. Skeletal Radiol. 2000;29:378–386. doi:10.1007/s002560000228.
[28] Goebel M, Rosa F, Tatsch K, Grillhoesl A, Hofmann GO, Kirschner MH. [Diagnosis of chronic osteitis of the bones in the extremities. Relative value of F–18 FDG–PET]. Unfallchirurg. 2007;110:859–866. doi:10.1007/s00113–007–1302–y [doi].
[29] Jiang MH, He C, Feng JM, Li ZH, Chen Z, Yan FH, et al. Magnetic resonance imaging parameter optimizations for diagnosis of periprosthetic infection and tumor recurrence in artificial joint replacement patients. Sci Rep. 2016;6:36995. doi:10.1038/srep36995.
[30] Jungmann PM, Ganter C, Schaeffeler CJ, Bauer JS, Baum T, Meier R, et al. View–angle tilting and slice–encoding metal artifact correction for artifact reduction in MRI: Experimental sequence optimization for orthopaedic tumor endoprostheses and clinical application. PLoS One. 2015;10: e0124922. doi:10.1371/journal.pone.0124922.
[31] Fritz J, Lurie B, Miller TT, Potter HG. MR Imaging of hip arthroplasty implants. RadioGraphics. 2014;34:E106–E132. doi:10.1148/rg.344140010.
[32] Aliprandi A, Sconfienza LM, Randelli F, Bandirali M, Di Leo G, Sardanelli F. Magnetic resonance imaging of painful total hip replacement: detection and characterisation of periprosthetic fluid collection and interobserver reproducibility. Radiol Med (Torino). 2012;117:85–95. doi:10.1007/s11547–011–0706–5.
[33] White LM, Kim JK, Mehta M, et al. Complications of total hip arthroplasty: MR imaging – initial experience. Radiology. 2000;215:254–262.
[34] Hargreaves BA, Worters PW, Pauly KB, Pauly JM, Koch KM, Gold GE. Metal–induced artifacts in MRI. Am J Roentgenol. 2011;197:547–555. doi:10.2214/AJR.11.7364.
[35] Hayter CL, Koff MF, Shah P, Koch KM, Miller TT, Potter HG. MRI after arthroplasty: comparison of MAVRIC and conventional fast spin–echo techniques. AJR Am J Roentgenol. 2011;197:W405–W411. doi:10.2214/AJR.11.6659.
[36] Sutter R, Ulbrich EJ, Jellus V, Nittka M, Pfirrmann CWA. Reduction of metal artifacts in patients with total hip arthroplasty with slice–encoding metal artifact correction and view–angle tilting mr imaging. Radiology. 2012;265:204–214. doi:10.1148/radiol.12112408.
[37] Choi SJ, Koch KM, Hargreaves BA, Stevens KJ, Gold GE. Metal artifact reduction with MAVRIC SL at 3–T MRI in patients with hip arthroplasty. AJR Am J Roentgenol. 2015;204:140–147. doi:10.2214/AJR.13.11785.